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Coker, II et al.

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(54) **ATTESTATION ARCHITECTURE AND SYSTEM**

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(52) **U.S. Cl.**

CPC ***H04L 63/0281*** (2013.01); *H04L 2209/127* (2013.01)

(58) **Field of Classification Search**

CPC . H04L 9/2371; H04L 9/3234; H04L 63/0876; H04L 2209/127

USPC 726/1, 22, 26; 713/151–153, 164–167, 713/187, 193, 194

See application file for complete search history.

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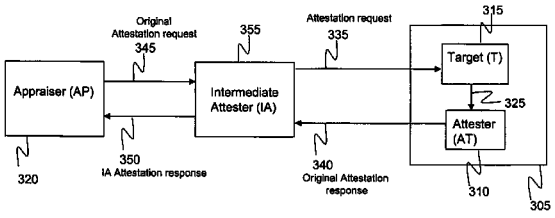
(57) **ABSTRACT**

An architecture and system are provided for flexible, composable attestation systems. Systems built according to this attestation architecture can be composed to accomplish complex attestation scenarios. The system is designed around composable components to permit flexible recombination. A system, method, and computer program product are provided for proving attestations to an appraiser regarding a target system. In an embodiment, an attestation request is sent from an appraiser to a target system, wherein the attestation request includes queries regarding properties of the target system needed by the appraiser to make trust decisions regarding the target system. The attestation request is forwarded from the target system to an attester which collects the requested data. The attester sends an attestation response to the appraiser, wherein the response includes at least information regarding properties of the target system requested by the appraiser in order to make a trust decision regarding the target system.

26 Claims, 8 Drawing Sheets



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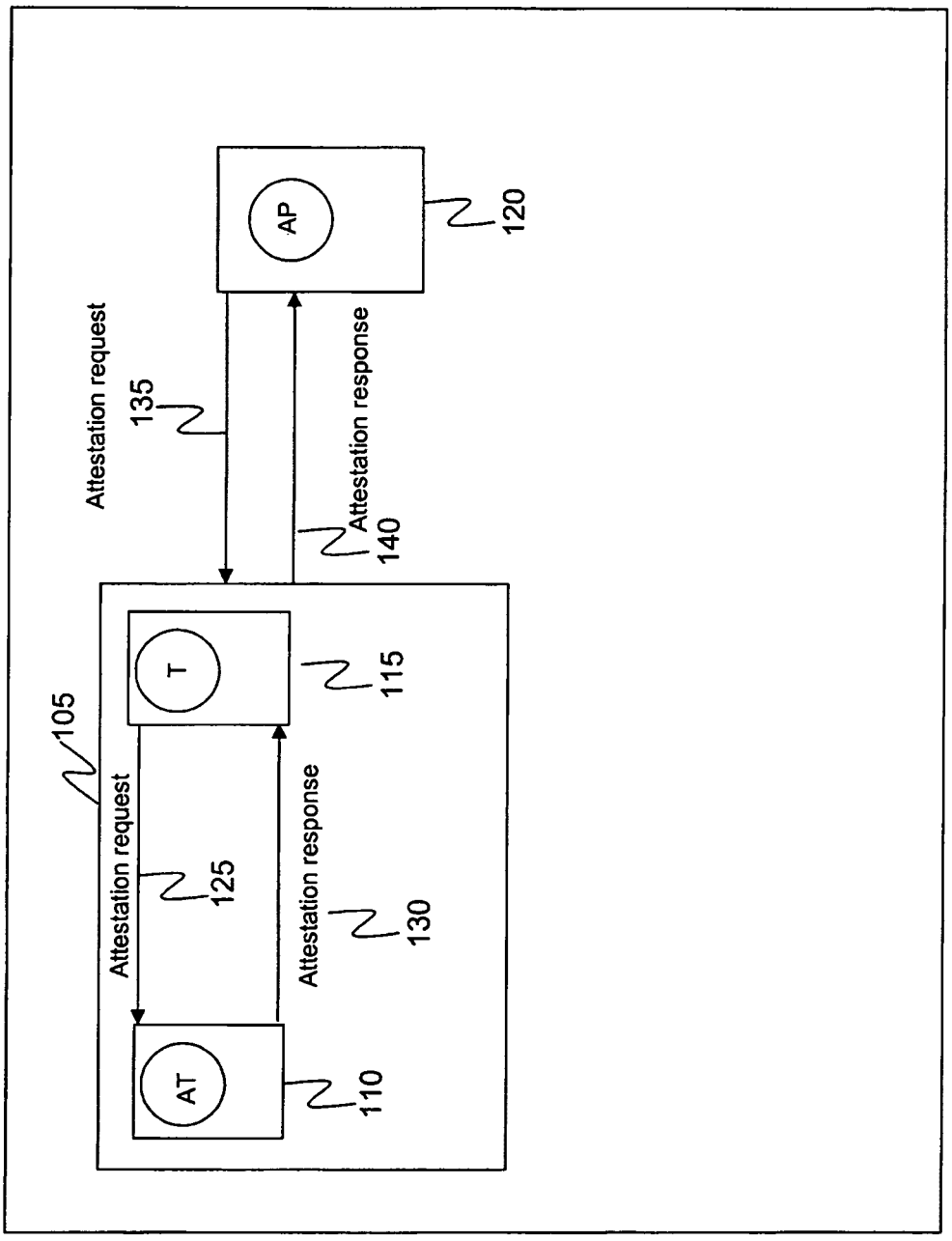
AP
120
Attestation request
135
Attestation response
140
105
T
115
Attestation request
125
Attestation response
130
AT
110
100

FIG. 1

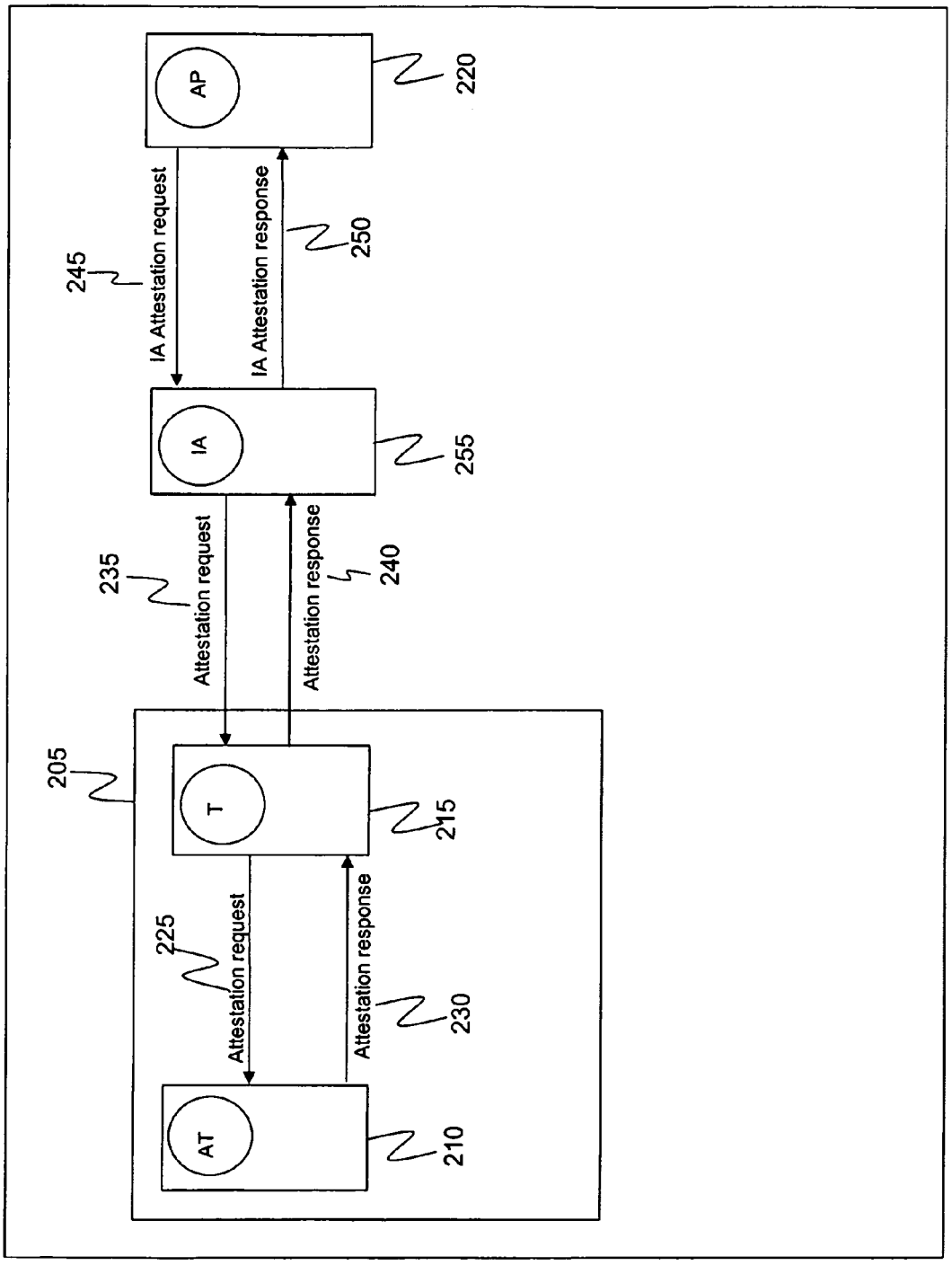
AP
220
IA Attestation request
245
IA Attestation response
250
IA
255
Attestation request
235
Attestation response
240
205
T
215
225
Attestation request
Attestation response
230
AT
210
200

FIG. 2

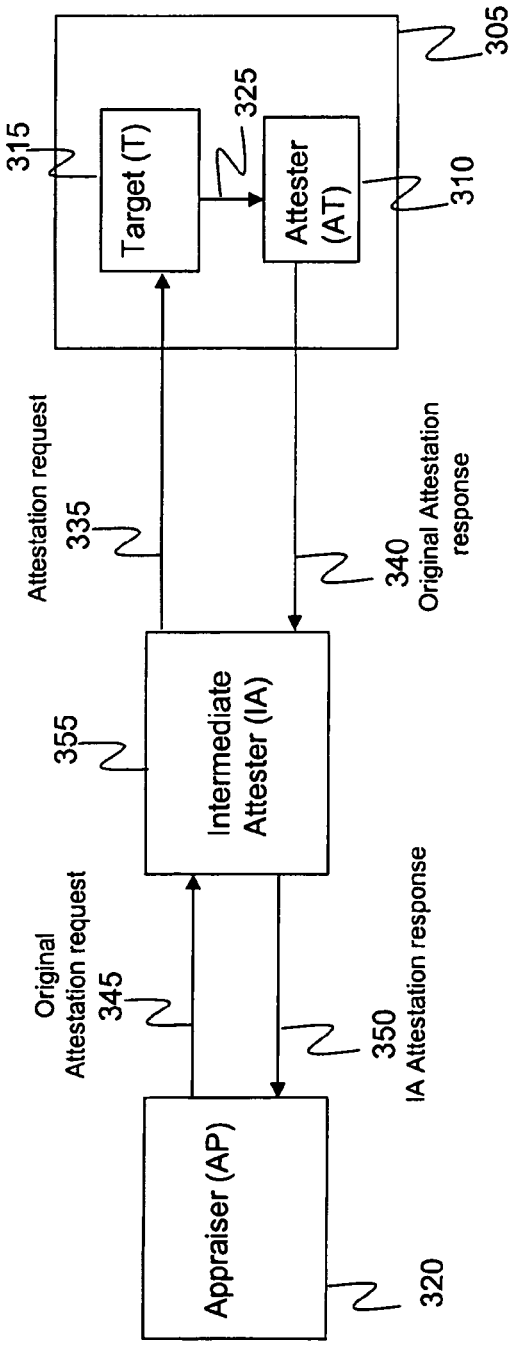
305
315
Target (T)
325
Attester (AT)
310
Attestation request
335
340
Original Attestation response
355
Intermediate Attester (IA)
Original Attestation request
345
350
IA Attestation response
Appraiser (AP)
320
300

FIG. 3

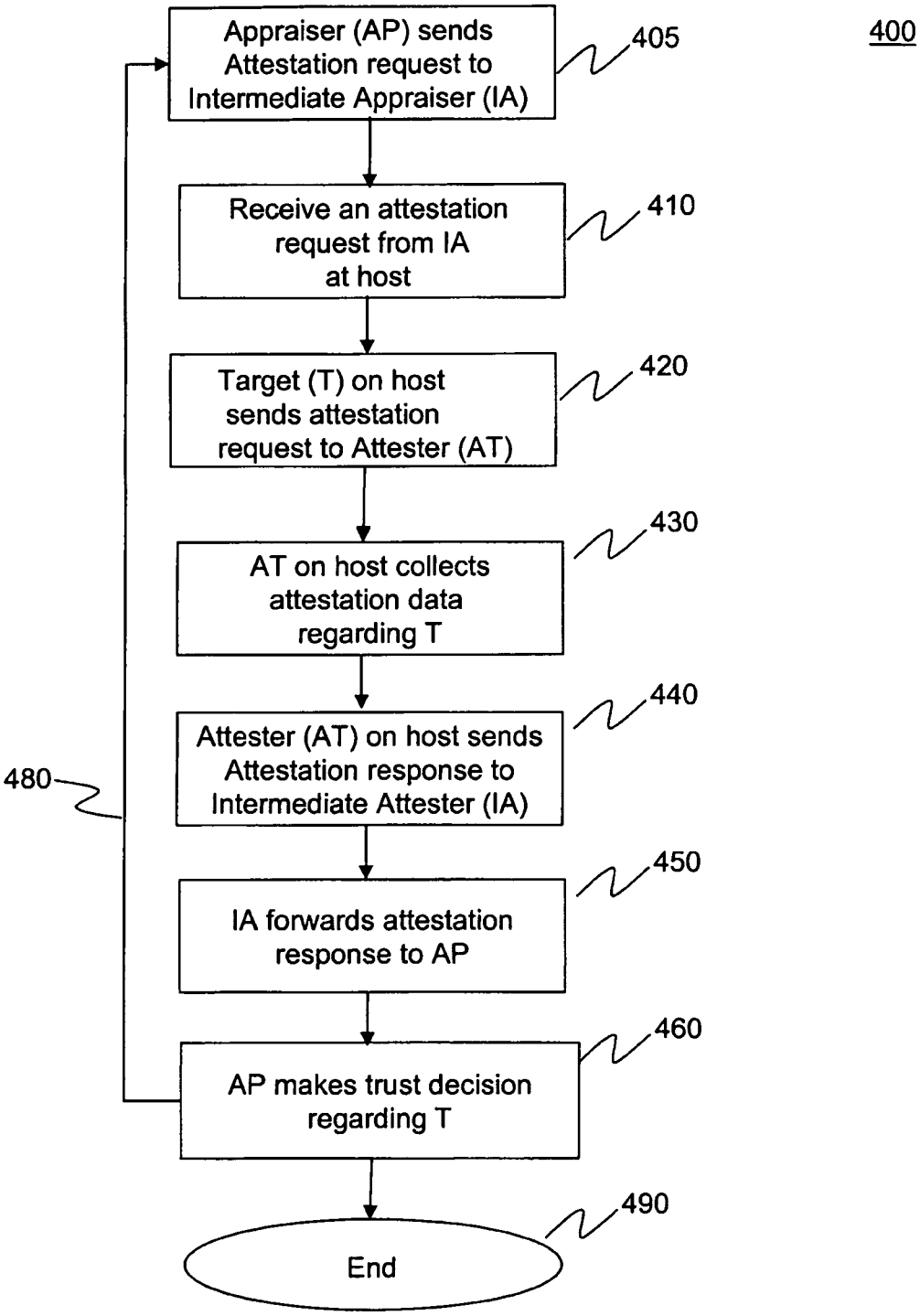
400
Appraiser (AP) sends Attestation request to Intermediate Appraiser (IA)
405
Receive an attestation request from IA at host
410
Target (T) on host sends attestation request to Attester (AT)
420
AT on host collects attestation data regarding T
430
Attester (AT) on host sends Attestation response to Intermediate Attester (IA)
440
480
IA forwards attestation response to AP
450
AP makes trust decision regarding T
460
End
490

FIG. 4

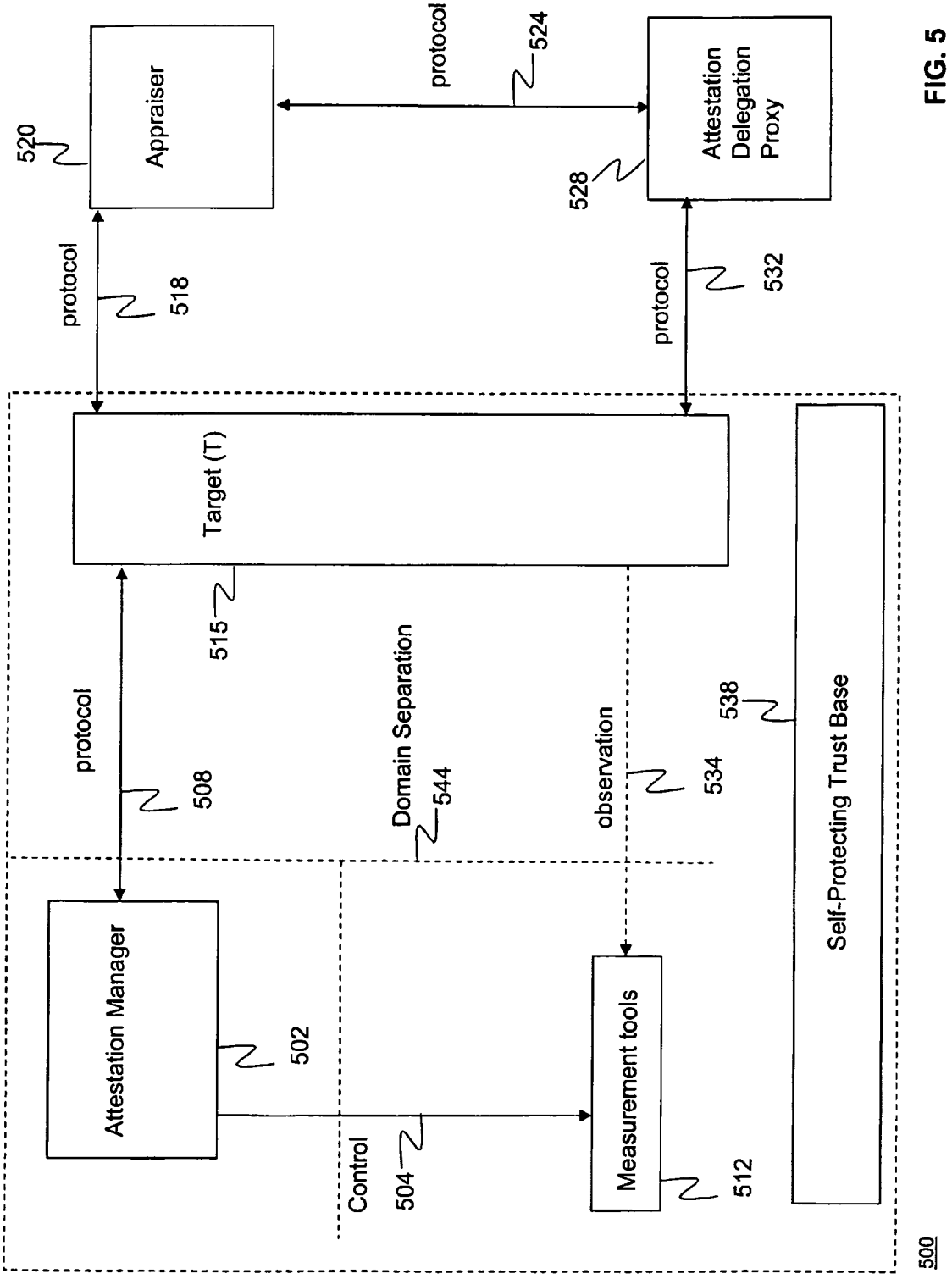
Appraiser
520
protocol
524
Attestation Delegation Proxy
528
protocol
518
protocol
532
Target (T)
515
protocol
508
Domain Separation
544
observation
534
538
Self-Protecting Trust Base
Attestation Manager
502
Control
504
Measurement tools
512
500

FIG. 5

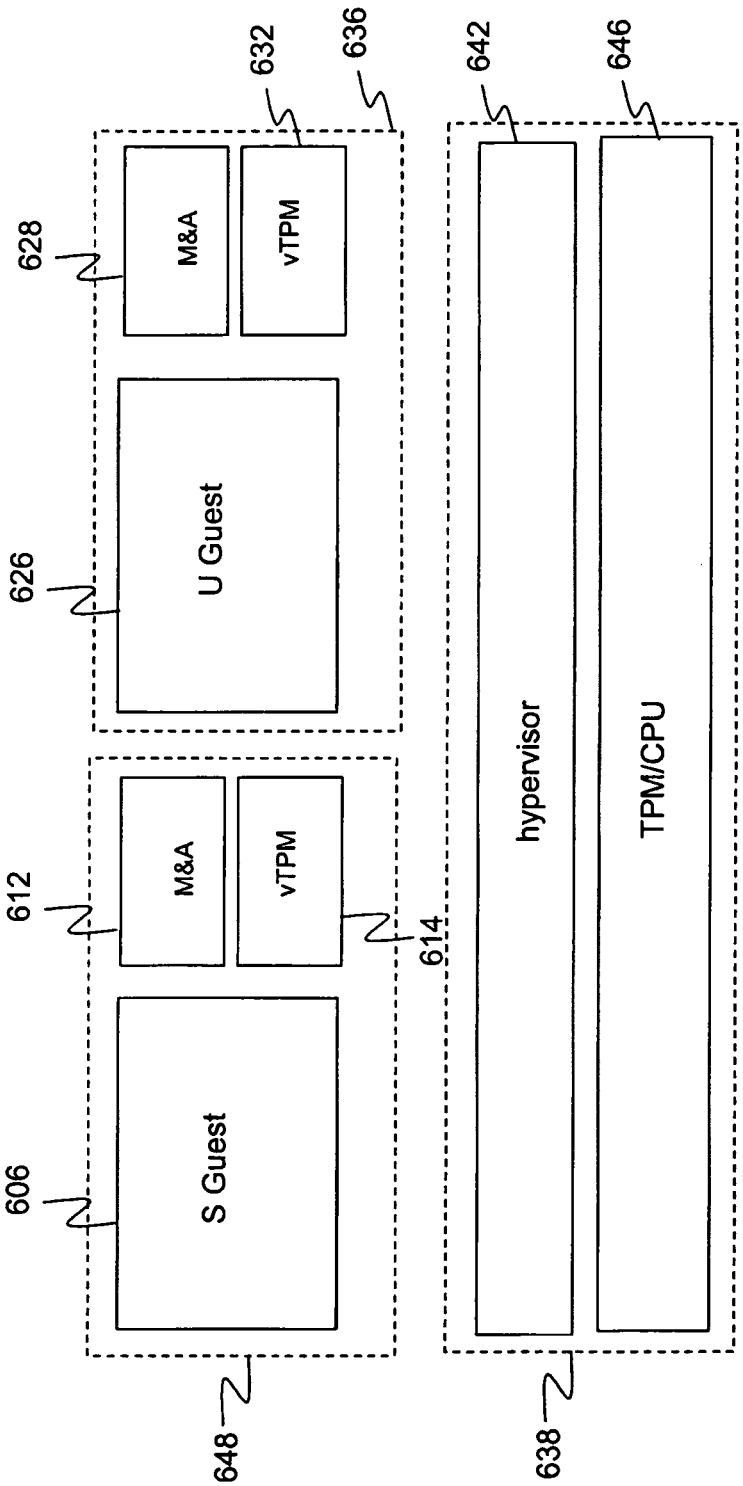
632
636
642
646
628
M&A
vTPM
626
U Guest
612
M&A
vTPM
614
hypervisor
TPM/CPU
606
S Guest
648
638
600

FIG. 6

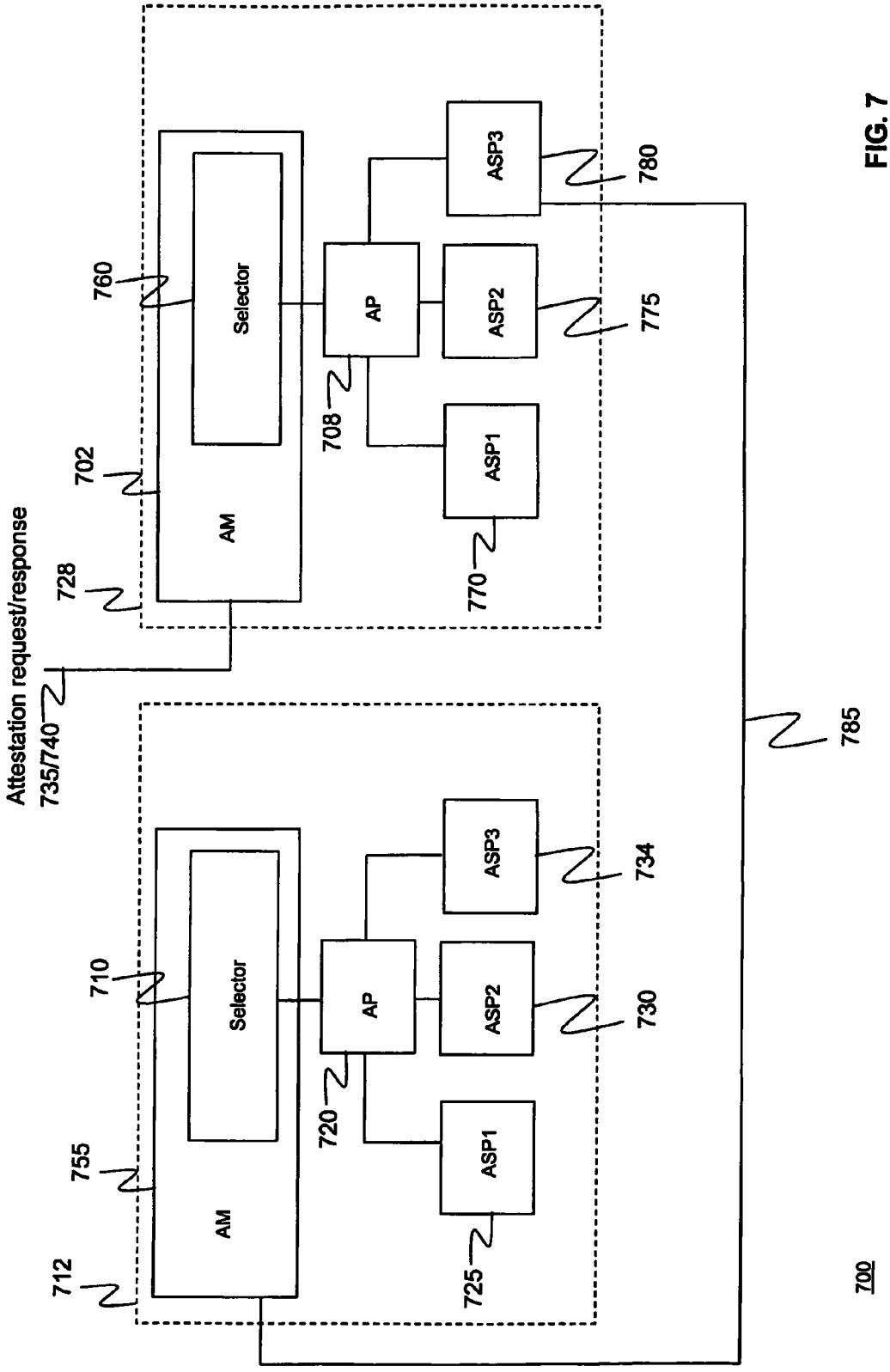
Attestation request/response
735/740
760
Selector
AM
702
728
AP
708
ASP3
ASP2
ASP1
780
775
770
785
710
Selector
AM
755
712
AP
720
ASP3
ASP2
ASP1
734
730
725
700

FIG. 7

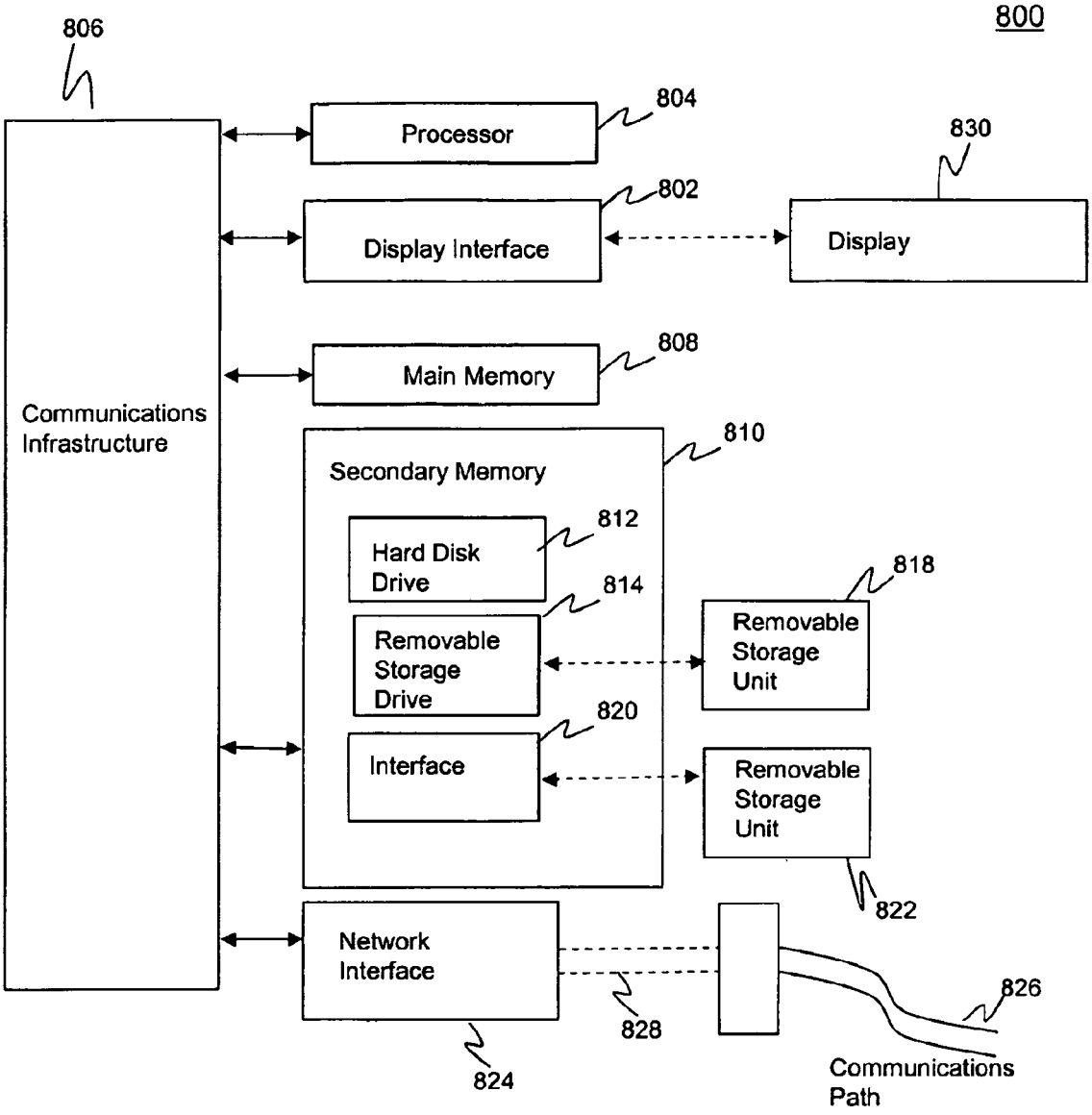
800
806
Communications Infrastructure
Processor
804
Display Interface
802
Display
830
Main Memory
808
Secondary Memory
810
Hard Disk Drive
812
Removable Storage Drive
814
Interface
820
Removable Storage Unit
818
Removable Storage Unit
822
Network Interface
824
828
826
Communications Path

FIG. 8

ATTESTATION ARCHITECTURE AND SYSTEM

STATEMENT UNDER MPEP 310

The U.S. Government has a paid-up license in this invention and the right in limited circumstances to require the patent owner to license others on reasonable terms as provided for by the terms of CE-COM contract W15P7T-05-C-F600 awarded by the National Security Agency.

BACKGROUND OF INVENTION

1. Field of the Invention

The present invention relates generally to network security and, more particularly, to attestation of properties of a remote system.

2. Description of the Background Art

A principal goal in trusted computing is to provide a user, resource owner, or service provider with reliable knowledge about a system. Through evaluation of the identity and integrity of a system, evidence is produced that the target will not engage in some class of misbehaviors.

Current attestation systems are components of computer systems that permit reliable statements of evidence about those systems to be conveyed to remote parties, including other computers. Through evaluation of the identity and integrity of a system, evidence is produced that the target will not engage in defined classes of misbehaviors. An example of a current attestation system is the remote attestation system developed by the Trusted Computing Group (TCG). The TCG introduced the Trusted Platform Module (TPM) and the associated concept of remote attestation. Remote attestation may be used to address a number of trust problems ranging from guaranteed invocation of software, delivery of premium content to trusted clients, assuaging mutual suspicion between clients, and more. As the requirements of applications cannot be known a priori, attestation systems and measurement systems alike must be flexible, providing for privacy, completeness of measurement, and trust in the basic collection and reporting mechanisms.

Existing attestation systems are narrowly focused and generally aimed at specific use-cases and therefore typically lack flexibility to address more general attestation problems. Further, existing definitions of attestation focus primarily on describing specific, narrow, and particular properties desirable in those use-cases.

Existing attestation definitions primarily focus on describing the particular properties desirable in limited, specific use-cases. Current attestation systems are created to work with one particular measurement system targeting one particular system of interest.

What is needed is an attestation architecture and system to enable trust in systems that are not monolithic and are made up of diverse hardware and software platforms. Also, each party to a given system's attestation desires its own measurements of its peers and themselves. A property that is sufficient for one party to use as evidence for a trust decision may not be for another; a set of information one user has no problem providing might cause privacy concerns for another. These varying needs are directly driven by what each party has at stake. The more one has to lose by inappropriate disclosure or incomplete knowledge, the stricter one's needs will be regarding privacy or complete measurement. Parties with strong demands of each other regarding authentication and measurement may be willing to give up more of their own private information in order to achieve their goals.

Accordingly, what is desired are attestation architectures and systems that are flexible enough to accommodate varying concepts of attestation. What is further needed are attestation systems designed around composable components that permit a flexible recombination of components to meet new needs. What is desired is an attestation architecture that can be used to design attestation systems which handle complex attestation scenarios and provide more complete attestation than is currently achievable.

SUMMARY OF INVENTION

Flexible methods, systems, and computer program products for performing attestation systems are disclosed. A flexible attestation architecture is disclosed. Systems built according to the architecture can be composed to accomplish complex attestation scenarios and to provide more complete attestation than is currently achievable. An attestation system that fulfils the requirements of the attestation architecture is disclosed.

In accordance with the methods and systems disclosed herein, it is not the attestation target which reports that its operating system kernel is unmodified. Instead, some distinct measurement component examines the attestation target and reports truthfully on the target no matter what the target reports about itself (i.e., the target is specifically not trusted).

The attestation system can be composed to accomplish complex attestation scenarios. The system is designed around composable components, permitting a flexible recombination to meet new needs. An open-ended framework for attestation is provided for safe support to sensitive or high-value activities on heterogeneous networks. An architecture for attestation is provided with a system implementation that adheres to this architecture.

Briefly stated, according to an embodiment, an attestation request is sent from an appraiser to a target system, wherein the attestation request includes queries regarding properties of the target needed by the appraiser to make trust decisions regarding the target system. The attestation request is forwarded from the target system to an attester which resides on the same physical host as the target and collects the data requested in the attestation request. The attester then sends an attestation response to the appraiser, wherein the response includes at least information regarding properties of the target system requested by the appraiser in order to make a trust decision regarding the target.

Trust decisions in the system are made by an appraiser that can support an access request made on behalf of the target system. These trust decisions are typically decisions about the expected behavior of the target. To enable decisions to be made on this basis, an attestation system is provided wherein an appraiser is provided with a significant amount of information including the knowledge that the state of the target is such that it will not transition into an unacceptable state while the appraiser still continues to trust it.

Attestation is the activity of making a claim to an appraiser about the properties of a target by supplying evidence which supports that claim. An attester is a party performing this activity. An appraiser's decision-making process based on attested information is appraisal. In the most commonly addressed class of attestations, each attestation provides a means for appraisers to infer that the target of the attestation will not engage in a class of misbehaviors. For example, if the target reports that its operating system kernel is unmodified, the attester has reason to trust reports from the target, and some appraiser trusts information provided by the attester, then that appraiser can infer that the target will not engage in

misbehaviors that might have occurred had the target's kernel been corrupted at the time of its measurement. The broader point of view makes a rich understanding of the related concepts of system measurement, attestation protocols, and system separation vital to successful attestation. Here there is a distinction between the measurement of a target system (the evidence) and the attestation itself.

To measure a target means to collect evidence about it through direct and local observation of it. Attestation about a target system will report measurements or conclusions inferred using measurements and possibly also other attestations.

Evidence may be attested to in a number of equivalent but semantically different forms depending on the attestation scenario. For example, the attestation may report raw evidence as directly observed, as reduced evidence (e.g. a hash of the raw evidence), or by substitution with a credential provided by a third party evaluator of the raw evidence. For example, an SSL certificate authority consumes many attestations as to the identity and practices of a target, and then produces a certificate attesting to the quality of a target. Also, a given target may wish to provide different information to different appraisers depending on the current trust relationships it has with those parties. A worthwhile desire in developing an attestation system is to resolve the mutual tension as well as possible given the contradictory nature of the parties' interests. In accordance with an embodiment of the invention, the appraiser demands frequent repeated attestations, re-evaluating its trust decisions often. The frequent repeated attestations are necessary because while it is possible to determine that a party will be sufficiently trustworthy for the 15 minutes (or other time period) after performing a given attestation, it is sometimes not feasible to determine that it will be so for a day. In accordance with another embodiment of the invention, the repeated attestations are repeated periodically at regular or irregular intervals.

The invention also includes a computer program product comprising a computer usable medium having computer program logic recorded thereon for enabling a processor to accomplish complex attestation scenarios. The computer program logic includes code to perform system attestation based upon properties of the target system instead of attestation based solely upon system identity.

The invention additionally includes a system capable of handling complex attestation scenarios. The system includes a first appraiser module to appraise targets, a second communication module to send and receive attestation requests and responses to between an appraiser and a target, a third target module to receive attestation requests, and a fourth attester module to receive and process attestation requests from a target.

Further features and advantages of the invention, as well as the structure and operation of various embodiments of the invention, are described in detail below with reference to the accompanying drawings. It is noted that the invention is not limited to the specific embodiments described herein. Such embodiments are presented herein for illustrative purposes only. Additional embodiments will be apparent to persons skilled in the relevant art(s) based on the teachings contained herein.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are incorporated herein and form a part of the specification, illustrate the present invention and, together with the description, further serve to explain the principles of the invention and to enable a person skilled in the relevant art to make and use the invention.

FIG. **1** illustrates an example attestation scenario.

FIG. **2** illustrates a complex attestation scenario, in accordance with an embodiment of the present invention.

FIG. **3** illustrates an attestation system, in accordance with an embodiment of the present invention.

FIG. **4** is a flowchart illustrating steps by which an attestation system processes and provides attestation information to an appraiser, in accordance with an embodiment of the present invention.

FIG. **5** illustrates the elements of an attestation architecture, in accordance with an embodiment of the present invention.

FIG. **6** illustrates a composable attestation platform, in accordance with an embodiment of the present invention.

FIG. **7** illustrates a composable Measurement and Attestation (M&A) architecture, in accordance with an embodiment of the present invention.

FIG. **8** depicts an example computer system in which the present invention may be implemented.

The present invention will now be described with reference to the accompanying drawings. In the drawings, generally, like reference numbers indicate identical or functionally similar elements. Additionally, generally, the left-most digit(s) of a reference number identifies the drawing in which the reference number first appears.

DETAILED DESCRIPTION

I. Introduction

While the present invention is described herein with reference to illustrative embodiments for particular applications, it should be understood that the invention is not limited thereto. Those skilled in the art with access to the teachings provided herein will recognize additional modifications, applications, and embodiments within the scope thereof and additional fields in which the invention would be of significant utility. Embodiments of the present invention are described primarily in the context of attestation targets, attesters, appraisers, intermediate attesters, attestation requests, attestation responses, and hosts wherein targets and attesters reside.

II. Attestation Scenarios

Attestation scenarios are exchanges between principals in attestation systems. These scenarios are used to illustrate security properties that are not explicit properties of the principals but rather the exchanges between the principals.

An exemplary attestation scenario is described in co pending U.S. patent application entitled, "Attesting to Properties of Measurements of a Remote System Without Providing Knowledge of the State of the Measured System," Ser. No. 12/173,229 (now U.S. Pat. No. 8,422,683, issued on Apr. 16, 2013), by Sniffen et al., filed concurrently herewith and incorporated in its entirety herein by reference.

FIG. **1** depicts an example attestation scenario. Attestation system **100** contains Target system (T **115**), Attester (AT **110**), and Appraiser (AP **120**). Target system **115** and attester **110** reside on the same physical host **105**, but there is a separation property causing them to be effectively different principals. Appraiser **120** demands attestation from target system **115** by sending attestation request **135**. Target system **115** via attestation request **125** asks attester **110** to examine target system **115** and collect information requested in attes-

tation request **135**. After gathering information necessary to fulfill attestation request **135**, attester **110** produces attestation **130** reflecting the examination of parts of target system **115**. This attestation is given back to target system **115** in attestation **130** that is resistant to tampering by target system **115**. In accordance with an embodiment of the invention, attestation responses **130** and **140** can be secured with a digital signature from attester **110**. For example, in an embodiment, attestation responses **130** and **140** may include a digital signature from attester **110** so that appraiser **120** is confident that the response came from attester **110**. In an embodiment of the present invention, attestation response **140** sent from target system **115** to appraiser **120** may contain a subset of information contained in attestation response **130** that was sent from attester **110** to target system **115**. For example, in an embodiment, information in attestation response **130** identifying attester **110** may be removed from attestation response **140** before response **140** is sent to appraiser **120**. In accordance with another embodiment, response **140** may be a forwarded copy of response **130** that contains identical information.

Target system **115** forwards attestation response **140** to appraiser **120** that sent attestation request **135**. In an embodiment of the present invention, attestation response **140** may be encrypted to ensure privacy. Details such as the specific contents of request **135** and response messages **130** and **140** will be apparent to those skilled in the relevant art. For an attestation to be believable, the measurements used to root the attestation must be produced by a trustworthy mechanism. Attester **110** is subject to the specific measurement requirements of appraiser **120**, and the only option for attester **110** to preserve privacy is to opt out entirely if attester **110** does not wish to fulfill request **135**. It is difficult in a simple attestation scenario depicted in FIG. **1** for attester **110** to verify the identity of a party such as appraiser **120** that will receive attestation measurements in attestation response **140**. Appraiser **120** cannot simply ask target system **115** about itself, as the purpose of the process depicted in attestation scenario **100** is to determine whether or not to trust target system **115**. It is not plausible to deal with attestation for making trust decisions without considering the examiner/attester **110** as a party separate from target system **115**.

FIG. **2** depicts a more complex attestation scenario **200** in accordance with an embodiment of the present invention. Scenario **200** shares some elements with scenario **100** depicted in FIG. **1**, but also includes intermediate attester IA **255**. If target system **215** wishes for another party such as appraiser **220** to make trust decisions about **215** without having to directly disclose measurements, this can be achieved by introducing a new party, in this case intermediate attester (IA **255**), that is trusted by target system **215** for privacy and is trusted by the receiver, appraiser **220**, for integrity. FIG. **2** does not depict how the trust party appraiser **220** is established, but it could be via another attestation as shown in FIG. **1**, or any other well known means acceptable to the respective parties.

Attestation system **200** contains target system (T **215**), attester (AT **210**), intermediate attester (IA **255**), and appraiser (AP **220**). Target system **215** and attester **210** reside on the same physical host **205**, but there is a separation property causing them to be effectively different principals. In accordance with an embodiment of the present invention, appraiser **220** demands attestation from target system **215** by sending intermediate attestation request **245** to intermediate attester **255**. In this example, intermediate attester **255** then sends target system **215** attestation request **235**. In an embodiment of the present invention, attestation request **235** sent from intermediate attester **255** to target system **215** may contain a subset of information contained in intermediate attestation request **245** that was sent from appraiser **220** to intermediate attester **255**. For example, in an embodiment, information in intermediate attestation request **245** identifying appraiser **220** may be removed from intermediate attestation request **245** before attestation request **235** is sent to target system **215**. In accordance with another embodiment, request **235** may be a forwarded copy of request **245** that contains identical information.

In accordance with an embodiment of the present invention, target system **215** then asks via attestation request **225** attester **210** to examine target system **215** parts and characteristics to gather information requested in attestation request **235**. In an embodiment of the present invention, attestation request **225** sent from target system **215** to attester **210** may contain a subset of information contained in attestation request **235** that was sent from intermediate attester **255** to target system **215**. For example, in an embodiment, information in attestation request **235** identifying intermediate attester **255** may be removed from attestation request **225** before it is sent from target system **215** to attester **210**. In accordance with another embodiment, request **225** may be a forwarded copy of request **235** that contains identical information.

After collecting information necessary to fulfill attestation request **235**, attester **210** produces attestation response **230** reflecting the examination of parts of system **215**. This attestation is given back to target system **215** in attestation response **230** that is resistant to tampering by target system **215**. In accordance with an embodiment of the invention, attestation **230** can be secured with a digital signature from attester **210**. Target system **215** forwards attestation response **240** to intermediate attester **255** that sent request **235**. In an embodiment of the present invention, attestation response **240** may be modified to ensure privacy. For example, in an embodiment, attestation response **240** may be encrypted to prevent unauthorized access by parties other than intermediate attester **255**. In an embodiment of the present invention, attestation response **240** sent from target system **215** to intermediate attester **255** may contain a subset of information contained in attestation response **230** that was sent from attester **210** to target system **215**. For example, in an embodiment, information in attestation response **230** identifying attester **210** may be removed from attestation response **240** before response **240** is sent to intermediate attester **255**. In accordance with another embodiment, response **240** may be a forwarded copy of response **230** that contains identical information.

Intermediate attester **255** then sends IA attestation response **250** to appraiser **220**. According to an embodiment of the invention, IA attestation response **250** may be a modified version of attestation response **240** that removes some details regarding target system **215**. For example, in an embodiment, attestation response **240** may include detailed platform and host-specific measurements for target system **215**, while IA attestation response **250** sent to appraiser **220** may be as simple as an intermediate attester-signed and time-stamped message claiming that target system **215** has certain abstract properties that appraiser **220** needs to know in order to trust target system **215**. Details such as the specific contents of requests **225** and **235**; and response messages **240** and **250** will be apparent to those skilled in the relevant art.

More particularly, in scenario **200**, attestation response **240** from target system **215** is sent to intermediate attester **255**, which performs an appraisal and then produces a new attestation response **250** which can be sent to appraiser **220**.

According to an embodiment of the present invention, the appraisal may be performed by examining evidence about past or future behavior of the target system **215**. For example, in an embodiment, the appraisal may be based on the state of programs installed and running on the target, changes during execution of programs, and measurements related to the hardware and software components that comprise target system **215**.

In this example, the original attestation response **240** sent to intermediate attester **255** may include detailed platform and host-specific measurements of target system **215**, while the modified attestation response **250** sent to AP **220** may be as simple as an intermediate attester-signed and time-stamped message effectively claiming that target system **215** has some given abstract property that appraiser **220** requires in order to trust target system **215**. Scenario **200** solves a privacy problem from the point of view of target system **215**. Scenario **200** also enables parties such as appraiser **220** to make trust decisions without knowing all of the individual details of target system **215** necessary to perform the right concrete local measurements on all remote parties that they may wish to trust. This "nesting" of attestations is a very powerful idea which can be used to introduce a great deal of flexibility in an attestation system. SSL certificate authority is an example of nested attestation. A SSL certificate authority is similar to the intermediate attester **255** party depicted in FIG. **2**, but SSL certificate authority operates offline and not online as intermediate attester **255** does.

Scenario **200** and the trust management under it abstracts away from the specifics of the properties desired and achieved by principals such as intermediate attester **255**, appraiser **220**, and target system **215**. This abstraction allows for easy development and analysis of a number of flexible attestation scenarios to cover most common cases. Scenarios **100** and **200** are illustrative examples, and do not encompass all possible attestation interactions.

In accordance with an embodiment of the present invention, the information about target system **215** provided in attestation response **240** reflects the running system on target system **215**, rather than just images about target system **215** stored on disk. While some measurement tools may collect and deliver start-up time information about a target such as target system **215**, others will need to inspect the current state of an active target. The attestation architecture provided herein ensures that such tools have access to the live state of the target. The architecture cannot predict the uses to which appraisers will put the information it delivers. Appraisers may need to make very different decisions, and in order to justify the decisions, appraisers such as appraiser **220** need to make different predictions about the future behavior of targets such as target system **215**.

The ability to compose scenarios such as **100** and **200** and measurement services in a flexible way to meet dynamic needs is more valuable from the point of view of attestation architecture than having a specific known set of possible known interactions. Trust engineering can become very complex, and that complexity is much more difficult to manage if one must start anew for each situation instead of just finding a set of pre-existing building blocks and composing them.

III. Attestation System

FIG. **3** is an attestation system **300** where an appraiser **320** is operable to make some determination regarding whether to trust target system **315**. In order to accomplish this, appraiser **320** submits an original attestation request **345** to intermediate attester **355**, in accordance with an embodiment of the present invention. Upon receipt of original attestation request **345**, intermediate attester **355** sends attestation request **335** to target system **315**.

In accordance with an embodiment of the present invention, original attestation request **345** may contain different information that what is contained in attestation request **335** so that information about appraiser **320** is excluded from attestation request **335** that is sent to target system **315**. In accordance with another embodiment of the present invention, original attestation request **345** and attestation request **335** may be encrypted to ensure privacy of information contained within the requests.

After target system **315** receives attestation request **335**, the request is forwarded to attester **335** as request **325**, in accordance with an embodiment of the present invention. In accordance with an embodiment of the present invention, attestation request **325** may contain different information that what is contained in attestation request **335** so that information about intermediate attester **355** is excluded from request **325** that is sent to attester **310**. For example, in an embodiment, request **325** may contain a subset of information in request **335** with some information about intermediate attester **355** is excluded from request **325** sent to attester **310**. Attester **310** is operable to determine system information regarding target system **315** and to transmit that information to intermediate attester **355** in attestation response **340**.

Attester **310** may be provided to target system **315** by an adversary (e.g., appraiser **320** or intermediate attester **355**). In accordance with an embodiment of the present invention, attester **310** is installed on the same platform **330** as target system **315** prior to the initiation of any communications with intermediate attester **355**. In accordance with an additional embodiment of the present invention, appraiser **320** or intermediate attester **355** provides attester **310** to platform **330** upon initiating communications including attestation request **335**. This example embodiment is described herein solely for purposes of illustration, and not limitation.

In accordance with an embodiment of the present invention, attester **310** sends original attestation response **340** to intermediate attester **355**. Intermediate attester **355** receives response **340** and sends attestation response **345** to appraiser **320**.

In accordance with an embodiment of the present invention, original attestation response **340** may contain different information that what is contained in attestation response **345** so that some information about target **335** is excluded from the intermediate attester attestation response **350** that is sent to appraiser **320**. In accordance with another embodiment of the present invention, original attestation response **340** and intermediate attester attestation response **350** may be encrypted to ensure privacy of information contained within the responses.

In accordance with an embodiment of the invention, original attestation request **345** may be routed directly from appraiser **320** to target system **315** without being sent to or modified by intermediate attester **355**. In accordance with another embodiment of the invention, original attestation response **340** may be routed directly from attester **310** to appraiser **320** without being sent to or modified by intermediate attester **355**.

FIG. **4** is a flowchart **400** illustrating steps by which an attestation system, such as system **300** depicted in FIG. **3** provides attestation information to appraiser **320**, according to an embodiment of the present invention.

More particularly, flowchart **400** illustrates the steps by which the target sends attestation information to the appraiser for its use to make trust decisions regarding the target. Flow-

chart **400** is described with reference to the embodiment of FIG. **3**. However, flowchart **400** is not limited to that example embodiment. Note that the steps in the flowchart do not necessarily have to occur in the order shown.

The method begins at step **405** where an Appraiser (AP **320**) sends an attestation request to an intermediate attester (IA **355**).

In step **410**, attestation request **335** from the intermediate attester **335** is received at a host containing the target of the attestation.

In step **420**, target system **315** sends attestation request **325** to an attester **310** residing on host **305**.

In step **430**, attester **310** collects attestation data regarding target system **315**.

In step **440**, attester **310** sends original attestation response **340** from host **305** to intermediate attester **355**. As discussed above, original attestation response **340** sent in this step may be digitally signed by attester **310**.

In step **450**, intermediate attester **355** sends intermediate attester attestation response **350** to appraiser **320**. As discussed above, intermediate attester attestation response **350** forwarded in this step may be a modified version of original attestation response **340**.

In step **460**, appraiser **320** makes a trust decision regarding target system **315** based at least on information contained in intermediate attester attestation response **350**.

In accordance with an embodiment of the invention, the appraiser may demand frequent or periodic repeated attestations, re-evaluating its trust decisions regarding target system **315**. The repeated attestations are accomplished by executing step **480** to repeat steps **410-460**. For example, in an embodiment, step **480** is executed causing steps **410-460** to be repeated periodically at regular or irregular intervals.

After a trust decision has been made by appraiser **320** and no re-evaluations are needed, the method ends at step **490**.

IV. Attestation Architecture

In accordance with an embodiment of the present invention, an attestation architecture is described herein that is capable of delivering comprehensive information about a target. The architecture enables attestations regarding a target's full internal state to be made accessible to local measurement tools without a loss of privacy for users of the target platform. An object of the present invention is to avoid subjecting the target platform to attack by sending attestation responses that disclose un-patched vulnerabilities to an adversary.

According to an embodiment of the present invention, the target is able to enforce a policy governing which measurements of itself are sent to any given appraiser. Hence, the attestation architecture provided herein allows the appraiser to be identified to the target. This attestation policy may distinguish kinds of information that may be delivered within attestation responses to different appraisers. According to an additional embodiment of the present invention, the attestation policy may be dynamic, relying on current run-time information for individual disclosure decisions. For example, in an embodiment, a decision to disclose information may require that the appraiser provide an attestation to the target about its own state.

According to an embodiment of the present invention, the semantic content of attestations is explicit. For example, in an embodiment, the identity of the target is explicitly represented in a form that the appraiser can use to determine whether a number of different attestations concern the same target. According to an embodiment of the present invention, the appraiser is able to infer consequences from a number of different attestations. For example, when several measurements are needed in order to make a prediction about the behavior of the target, an appraiser can infer consequences from these several measurements of the target. According to the attestation architecture provided herein, the semantics of individual attestations are uniform, and they are composable using valid logical inferences.

According to an embodiment of the present invention, the attestation mechanism itself is able to provide the appraiser with evidence that individual attestations are reliable. For example, the attestation architecture is identified to the appraiser and target. As would be recognized by persons of skill in the art, there may be variations in how different systems fulfill the requirements of the attestation architecture disclosed herein. These variations may arise due to limited forms of evidence available regarding a target which may suffice for an appraiser, or evidence that has aged to an extent that it may be older than what would normally be accepted. When different degrees of adherence to the architecture elements are designed into a system, then the variation is static. When the system adjusts at run-time to provide different degrees of evidence in different situations, or when different peers are the appraiser, then the variation is dynamic.

An attestation system designed according to the attestation architecture must have the following capabilities. The attestation system:

a) measures diverse aspects of the target of attestation;

b) has separate domains to ensure that the measurement tools can prepare their results without interference from the (possibly unreliable) target of attestation;

c) protects itself or a core trust base with the domain separation mechanism by ensuring that it cannot be weakened without this fact being evident from the content of attestations; and

d) delegates attestation by having attestation proxies collect detailed measurements, convincing evidence, and summarizing the measurements and evidence to selected peers, when a target does not permit the full facts to be widely shared; and manages attestation to handle attestation queries by invoking suitable measurement tools, delivering the results to the appraiser or a proxy as constrained by policies.

A. Measurement Tools

Providing comprehensive information about a system requires the ability to provide a collection of measurement tools that jointly and comprehensively measure a target. Comprehensive measurement of a system requires more than simply the ability to read all of the data contained in that system. It also means that some measurement tools must understand the structure of what they are measuring. For example, merely scanning and hashing memory used by a target's operating system kernel may be insufficient to provide useful measurements of the target. Usefulness is judged in terms of the appraiser's needs, and typically involves evidence about the past or future behavior of the target. The state of a program changes during execution, and therefore cannot be measured by simple hashing. For this reason, measuring complex system components requires knowing the structure of the targets. Some trust decisions require these structure-sensitive measurements. Different measurement tools must be produced for measuring components with different structure. Thus, the complete set of such tools that will be desired is not knowable ahead of time without restricting the target systems from ever adding any new future applications. The attestation architecture disclosed herein supports a collection of specialized measurement tools, and in order to be able to provide evidence for arbitrary future attestations it also supports adding new tools to the collection over time. In addition

to measurement capacity being comprehensive, freshness of target attestation information is also supported by the architecture. Measurements cannot always be performed a priori because appraisers must be able to measure various parts of a target system on demand. These demands are made from the point of view of an appraiser. The attestation architecture presented herein enables a remote party to trigger measurement; as it is insufficient to only have runtime measurement occur via periodic automatic re-measurement triggered by the measurement system or tools.

B. Domain Separation

In accordance with an embodiment of the invention, a domain separation mechanism separates the attestation manager from the target and the measurement tools. According to an embodiment of the present, invention domain separation may be achieved by a hardware component that provides runtime measurements of the domain separation mechanism.

For a measurement tool to provide information about a target of attestation, the measurement tool must be able to deliver accurate results even when the target is corrupted. The measurement too must first have access to the target's state so as to be able to distinguish whether that target is corrupted or uncorrupted. This state includes the target's executable code but also modifiable data structures that determine whether its future behavior will be acceptable. The measurement tool's state must also be inaccessible to the target, so that even if the target is corrupted, it cannot interfere with the results of the measurement. According to an embodiment of the invention, this separation is achieved by virtualizing the target, so that the measurement tool runs in a separate virtual machine (VM) from the target. The virtual machine monitor must then be able to control visibility across multiple virtual machines so that the measurement tool has read access to the target. It must also ensure that the target does not have any control over the measurement tool. There may be a message-passing channel established between them, but the hypervisor/VMM must be able to ensure transparent visibility of the measurement tool into the target and protection of those tools from the target.

C. Self-Protecting Trust Base

To achieve domain separation it is necessary in order to have trust in attestations and specifically in the integrity of the measurement tools. The attestation system's trust comes from components which are simple enough or sufficiently evaluated so that one can be convinced that they do not require re-measurement after they have been running. Part of this core includes the hardware used as a Trusted Computing Base. Any other component must either be measurable from a place that it cannot control or must be sufficiently measured via a static startup measurement taken before it begins operating. The self-protecting trust base is more than just a trusted static subset of a system. The trust base is sufficiently simple and static so that re-measurement is not required, but also is also sufficiently rich to bootstrap measurements and attestations. Anything performing measurement and attestation on the platform will in turn require measurement and attestation about itself in order to convince an appraiser of its trustworthiness. It must be ensured that this chain "bottoms out" at something sufficient to perform certain essential measurements and attestations to support the chain above it while being simple enough that static startup-time measurements are sufficient to determine trust. The content of this static trust base must be determined.

D. Attestation Proxies

In accordance with an embodiment of the invention, the appraiser delegates many aspects of determining the quality of the target to specialists called attestation proxies. Insight into the state of the target is made available by the proxies while also allowing a target to choose and enforce a policy on the disclosure of information about its state. This is accomplished by allowing an appraiser and target to agree on an attestation proxy that is partially and mutually trusted by both the appraiser and target. According to an embodiment of the present invention, the target is configured to trust the proxy to disclose only information about its state which is of limited sensitivity. For example, the appraiser may trust the proxy to make statements only when they are warranted by appropriately fresh and comprehensive information about the target. Proxies can function as specialists acting on behalf of the appraiser. Expertise is needed to interpret detailed measurements, such as those needed to predict behavioral properties about an operating system. An appraiser may get more reliable information and more usable information from an attestation proxy than it would be able to extract on its own from the comprehensive data. According to an embodiment of the present invention, maintainers of an attestation proxy ensure that it has up-to-date information about the strengths and weaknesses of specific system versions or configurations.

E. Protocols

Delegations to attestation proxies require protocols that allow the principals to ensure they are communicating with appropriate proxies. These protocols must supply the principals with messages that unambiguously answer the principals' queries. Any well known communication protocol can be used. These delegations, combined with attestations fulfilling architecture requirements discussed above, enable a powerful new attestation capability.

An appraiser may compose separate layered or orthogonal attestations, involving different proxies, in order to make a judgment.

F. Attestation Manager

The attestation architecture presented herein is flexible and systems built according to the architecture respond meaningfully to different requests from different appraisers without knowing or having pre-arranged what every possible combination of attestations might be. The architectural component referred to as the Attestation Manager enables this flexibility. The Attestation Manager component contains a registry of all of the measurement and attestation tools currently on the platform, and a description of the semantic content produced by each. This component can select at runtime the appropriate services needed to answer any query which could be answered by some subset of the measurement and attestation capabilities currently on the system. The Attestation Manager is involved in nearly every remote attestation, and it also enforces the constrained disclosure called for by the architecture. The Attestation Manager can restrict the services it selects based on the identity of the party the information would be released to, according to locally-stored access policies. In order to defend this capability from both the untrusted target of attestations and also from potentially-vulnerable measurement tools, the Attestation Manager is protected via domain separation.

Attestation responses use cryptography (i.e., encryption) in order to protect communications from adversaries. This same protection, taken together with domain separation, means that the target can be safely used as an intermediary for communication with appraisers or proxies. This leads to the very beneficial result that an Attestation Manager can be a purely local service; it does not need to be directly accessible by any remote parties.

FIG. **5** illustrates the elements of an attestation architecture, in accordance with an embodiment of the present invention. Attestation manager **502** communicates with target system **515** via protocol **508**. Attestation manager **502** is

protected by domain separation **544** and sends control information **504** to measurement tools **512**. Target system **515** communicates with appraiser **520** via protocol **518**. In an embodiment of the present invention, target system **515** sends attestation requests. For example, in an embodiment, with reference to FIG. **2**, attestation request **225** may be sent to appraiser **220** using protocol **518**. Appraiser **520** communicates with attestation delegation proxy **528** via protocol **524**. Attestation proxy **528** communicates with target system **515** via protocol **532**. In an embodiment of the present invention, attestation delegation proxy **528** sends attestation responses, such as attestation response **230** depicted in FIG. **2**, to target system **515** using protocol **532**. Target system **515** then sends observation **534** to measurement tools **512**. In an embodiment of the present invention, observation **534** may contain an attestation response. For example, in an embodiment, with reference to FIG. **2**, attestation response **240** may be sent using protocol **518**. Self-protecting trust base **538** includes at least hardware that is used as the platform's Trusted Computing Base. In an embodiment of the present invention, self-protecting trust base **538** is composed of components which are simple enough or sufficiently evaluated so that principals such as attestation manager **502** and target system **515** can be convinced that they do need to re-measure the components after they have been running.

FIG. **6** illustrates the attestation architecture implemented as a composable attestation platform **600**, in accordance with an embodiment of the present invention. Hypervisor **642**, together with TPM/CPU **646**, serves self-protecting trust base **638**. The representation in FIG. **6** is abstract, as the implementation of the attestation architecture is not tied to features specific to any one virtual machine monitor or microprocessor. Supervisor guest (S guest **606**) contains the platform support package. User guest (U guest **626**) runs the user's "normal" operating system.

Virtualized TPM (vTPM **614**) hardware resource provides TPM capabilities for both the Supervisor **648** and User **636** environments. Both environments possess measurement and attestation services ("M&A"). M&A service **612** is part of supervisor environment **648** and M&A service **628** is part of user environment **636**.

The construction and operation of hypervisor **642** and each guest (e.g., supervisor guest **606** and user guest **626**) coincides with the collection of evidence reportable in attestations of the platform. Multiple, separate M&A capabilities are needed because evidence reported from a single party such as supervisor guest **606** or user guest **626** may not be sufficient. For example, in an embodiment, with reference to FIG. **1**, user M&A service **628** may act as the target system **115** role, and supervisor M&A service **612** may act as the attester **110** role.

To manage a diversity of measurement and attestation requirements, virtual machine (vTPM **632**) is dedicated to measurement and attestation (M&A) of a guest.

Hypervisor **642** is integral to self-protecting trust base **638**. Hypervisor **642** controls sharing and provides domain separation for the system.

Separation of the M&A **628** and user guest **626** elements is transparent to the target system and the attester. For example, in an embodiment, with reference to FIG. **1**, target system **115** and attester **110** does not view M&A service **628** as a separate entity from user guest **626**. User guest **626** directs or routes proxy responses from M&A service **628** back to appraisers. For example, in an embodiment, with reference to FIG. **1**, M&A service **628** routes attestation response **140** to appraiser **120**.

In order to thoroughly or deeply assess platform **600**, one may need to connect attestations together across the supervisor **648** and user **636** environments. The need for thorough or deep platform assessment can be satisfied with semantically explicit attestations as previously discussed.

FIG. **7** illustrates a composable Measurement and Attestation (M&A) architecture **700**, in accordance with an embodiment of the present invention. With continued reference to FIG. **6**, M&A **612** and M&A **628** include three components: attestation manager (AM **705**), attestation protocols (AP **720** and AP **765**), and attestation service providers (ASP**1** **725**, ASP**2** **730**, ASP**3** **734**, ASP**1** **770**, ASP**2** **775**, and ASP**3** **780**).

Attestation manager **702** manages the attestation session, listening for incoming attestation request **735**, and using a subcomponent, selector **760** for initiating attestation protocol **765**. An attestation protocol such as AP **765** is a running instance of an attestation protocol initiated by selector **760** in response to attestation request **740**.

Attestation service providers (ASP**1** **725**, ASP**2** **730**, ASP**3** **734**, ASP**1** **770**, ASP**2** **775**, and ASP**3** **780**) are subcomponents of attestation protocols. In this specific example, attestation service providers ASP**1** **725**, ASP**2** **730**, and ASP**3** **734** are subcomponents of attestation protocol **720**; and attestation service providers ASP**1** **770**, ASP**2** **775**, and ASP**3** **780** are subcomponents of attestation protocol **708**. Each attestation service provider performs a well-defined service in the attestation protocol and as defined serve a critical role in satisfying attestation architecture requirements for the platform. With continued reference to FIG. **6**, ASP**1** **725**, ASP**2** **730**, and ASP**3** **734** are integrity measurement systems, wrappers for calls to TPM **646**, vTPM **614**, vTPM **632**, or invocation of other services.

As a result of separating key services into attestation protocols **708** and **720** which may be used by different attestation service providers such as ASP**1** **725** and ASP**1** **770**, and abstracting over attestation protocols **708** and **720** using attestation manager **702** or **755**, an extensible system is created. This extensible attestation system has the ability to add new services and protocols without the need to redesign or re-evaluate the entire system for each addition.

Selector **760** is the mechanism for enforcing the policy of the client by instantiating attestation protocols and attestation service providers that conform to the policy for a given scenario. Implementation **700** uses a method referred to as "Call by Contract" for selector **760**.

Attestations may be chained across platform **700** by the use of attestation service provider ASP**3** **780** that makes attestation requests **785** to another M&A environment **702** and relays or uses the attestation responses. With reference to FIG. **6**, FIG. **7** depicts a composable set of components **700** that can be used in an attestation, including an attestation service provider in user M&A service **628** which makes an attestation request to supervisor M&A service **612**, enabling attestations which satisfy the requirements of the attestation architecture.

Attestation protocols within M&A **612** or and **628** may demand attestation requests/responses **740** as well as providing responses **785**, and may use attestation service providers for verification of the properties asserted by such attestations.

IV. Example Computer System Implementation

Various aspects of the present invention can be implemented by software, firmware, hardware, or a combination thereof. FIG. **8** illustrates an example computer system **800** in which the present invention, or portions thereof, can be implemented as computer-readable code. For example, the

methods illustrated by flowchart **400** of FIG. **4** can be implemented in system **800**. Various embodiments of the invention are described in terms of this example computer system **800**. After reading this description, it will become apparent to a person skilled in the relevant art how to implement the invention using other computer systems and/or computer architectures.

Computer system **800** includes one or more processors, such as processor **804**. Processor **804** can be a special purpose or a general purpose processor. Processor **804** is connected to a communication infrastructure **806** (for example, a bus or network).

Computer system **800** also includes a main memory **808**, preferably random access memory (RAM), and may also include a secondary memory **810**. Secondary memory **810** may include, for example, a hard disk drive **812**, a removable storage drive **814**, and/or a memory stick. Removable storage drive **814** may comprise a floppy disk drive, a magnetic tape drive, an optical disk drive, a flash memory, or the like. The removable storage drive **814** reads from and/or writes to a removable storage unit **818** in a well known manner. Removable storage unit **818** may comprise a floppy disk, magnetic tape, optical disk, etc. which is read by and written to by removable storage drive **814**. As will be appreciated by persons skilled in the relevant art(s), removable storage unit **818** includes a computer usable storage medium having stored therein computer software and/or data.

In alternative implementations, secondary memory **810** may include other similar means for allowing computer programs or other instructions to be loaded into computer system **800**. Such means may include, for example, a removable storage unit **822** and an interface **820**. Examples of such means may include a program cartridge and cartridge interface (such as that found in video game devices), a removable memory chip (such as an EPROM, or PROM) and associated socket, and other removable storage units **822** and interfaces **820** which allow software and data to be transferred from the removable storage unit **822** to computer system **800**.

Computer system **800** may also include a communications interface **824**. Communications interface **824** allows software and data to be transferred between computer system **800** and external devices. Communications interface **824** may include a modem, a network interface (such as an Ethernet card), a communications port, a PCMCIA slot and card, or the like. Software and data transferred via communications interface **824** are in the form of signals which may be electronic, electromagnetic, optical, or other signals capable of being received by communications interface **824**. These signals are provided to communications interface **824** via a communications path **826**. Communications path **826** carries signals and may be implemented using wire or cable, fiber optics, a phone line, a cellular phone link, an RF link or other communications channels.

In this document, the terms "computer program medium" and "computer usable medium" are used to generally refer to media such as removable storage unit **818**, removable storage unit **822**, and a hard disk installed in hard disk drive **812**. Signals carried over communications path **826** can also embody the logic described herein. Computer program medium and computer usable medium can also refer to memories, such as main memory **808** and secondary memory **810**, which can be memory semiconductors (e.g. DRAMs, etc.). These computer program products are means for providing software to computer system **800**.

Computer programs (also called computer control logic) are stored in main memory **808** and/or secondary memory **810**. Computer programs may also be received via communications interface **824**. Such computer programs, when executed, enable computer system **800** to implement the present invention as discussed herein. In particular, the computer programs, when executed, enable processor **804** to implement the processes of the present invention, such as the steps in the methods illustrated by flowchart **400** of FIG. **4** discussed above. Accordingly, such computer programs represent controllers of the computer system **800**. Where the invention is implemented using software, the software may be stored in a computer program product and loaded into computer system **800** using removable storage drive **814**, interface **820**, hard drive **812**, or communications interface **824**.

The invention is also directed to computer program products comprising software stored on any computer useable medium. Such software, when executed in one or more data processing device, causes a data processing device(s) to operate as described herein. Embodiments of the invention employ any computer useable or readable medium, known now or in the future. Examples of computer useable mediums include, but are not limited to, primary storage devices (e.g., any type of random access memory), secondary storage devices (e.g., hard drives, floppy disks, CD ROMS, ZIP disks, tapes, magnetic storage devices, optical storage devices, MEMS, nanotechnological storage device, etc.), and communication mediums (e.g., wired and wireless communications networks, local area networks, wide area networks, intranets, etc.).

VI. Conclusion

While various embodiments of the present invention have been described above, it should be understood that they have been presented by way of example only, and not limitation. It will be understood by those skilled in the relevant art(s) that various changes in form and details may be made therein without departing from the spirit and scope of the invention as defined in the appended claims. It should be understood that the invention is not limited to these examples. The invention is applicable to any elements operating as described herein. Accordingly, the breadth and scope of the present invention should not be limited by any of the above-described exemplary embodiments, but should be defined only in accordance with the following claims and their equivalents.

What is claimed is:

1. A method for making trust decisions regarding a target system, the method comprising:

(a) receiving an attestation request at the target system, wherein the attestation request includes queries regarding specific dynamic properties of the target system needed by an appraiser to make trust decisions regarding the target system, and wherein the attestation request contains a subset of information contained in an original request from the appraiser;

(b) sending the attestation request from the target system to an attester, wherein sending the attestation request from the target system to the attester comprises sending a subset of information contained in the attestation request to the attester;

(c) collecting information regarding the specific dynamic properties by invoking measurement agents that perform measurements on software executing on the target system, wherein the collected information corresponds to the subset of information sent from the target system to the attester;

(d) sending an attestation response from the attester to the appraiser, wherein the response includes at least information regarding the specific dynamic properties of the

target system requested by the appraiser in step (a) and information regarding the reliability of the attestation response, wherein the information regarding the reliability of the attestation response identifies an attestation architecture of the attester; and

(e) making a trust decision at the appraiser regarding the target system based on the information regarding the specific dynamic properties and the reliability of the attestation response contained in the attestation response.

2. The method of claim **1**, wherein step (a) comprises sending an encrypted attestation request from an appraiser to a target system.

3. The method of claim **1**, further comprising re-evaluating the trust decision of step (e) by repeating steps (a)-(d).

4. The method of claim **3**, wherein the re-evaluating is performed periodically.

5. The method of claim **1**, wherein step (d) comprises sending an attestation response that is resistant to tampering.

6. The method of claim **5**, wherein the attestation response is encrypted.

7. The method of claim **5**, wherein the attestation response contains a digital signature from the attester.

8. The method of claim **1**, wherein the target system resides on the same physical host as the attester.

9. The method of claim **8**, wherein there is a separation property causing the target system and the attester to be effectively different principals.

10. The method of claim **1**, wherein sending the attestation request comprises sending the attestation request to an attester residing on a same host as the target system.

11. A method for making trust decisions regarding a target system, the method comprising:

(a) sending a first attestation request from an appraiser to an intermediate attester, wherein the first request includes queries regarding specific dynamic properties of the target system needed by the appraiser to make trust decisions regarding the target system;

(b) receiving the first attestation request at the intermediate attester;

(c) modifying the first attestation request at the intermediate attester to generate a second attestation request comprising a subset of the information contained in the first attestation request;

(d) sending the second attestation request from the intermediate attester to the target system;

(e) receiving the second attestation request at the target system;

(f) forwarding the second attestation request from the target system to an attester, wherein forwarding the attestation request from the target system to the attester comprises sending a subset of information contained in the attestation request to the attester;

(g) collecting information regarding the specific dynamic properties by invoking measurement agents that perform measurements on software executing on the target system, wherein the collected information corresponds to the subset of information forwarded from the target system to the attester;

(h) sending a first attestation response from the attester to the intermediate attester, wherein the first response includes at least information regarding the specific dynamic properties of the target system requested by the appraiser in step (a) and information regarding the reliability of the attestation response, wherein the information regarding the reliability of the attestation response identifies an attestation architecture of the attester;

(i) modifying the first attestation response at the intermediate attester;

(j) sending a second attestation response from the intermediate attester to the appraiser; and

(k) making a trust decision at the appraiser regarding the target system based on information regarding the specific dynamic properties and the reliability of the attestation response contained in the second attestation response.

12. The method of claim **11**, further comprising re-evaluating the trust decision of step (k) by repeating steps (a)-(j).

13. The method of claim **12**, wherein the re-evaluating is performed periodically.

14. The method of claim **11**, wherein step (a) comprises sending an encrypted attestation request from an appraiser to an intermediate attester.

15. The method of claim **11**, wherein the modifying in step (i) comprises modifying the first attestation response to exclude some detailed platform and host-specific measurements for the target system.

16. The method of claim **15**, wherein the second attestation response includes at least a time-stamped message claiming that the target system has some given abstract property that the appraiser requires in order to trust the target system.

17. The method of claim **11**, wherein step (j) comprises sending a second attestation response that is resistant to tampering.

18. The method of claim **17**, wherein the second attestation response is encrypted.

19. The method of claim **17**, wherein the second attestation response contains a digital signature from the attester.

20. The method of claim **11**, wherein the target system resides on the same physical host as the attester.

21. The method of claim **20**, wherein there is a separation property causing the target system and the attester to be effectively different principals.

22. The method of claim **11**, wherein forwarding the second attestation request comprises forwarding the second attestation request to an attester residing on the same host as the target system.

23. A computer program product comprising a non-transitory computer usable medium having computer program logic recorded thereon for enabling a processor to perform operations to make trust decisions regarding a target system, the operations comprising:

sending an attestation request to the target system, wherein the attestation request contains a subset of information contained in an original request from an appraiser;

receiving the attestation request from an appraiser at the target system, wherein the request includes queries regarding specific dynamic properties of the target system needed by the appraiser to make trust decisions regarding the target system;

sending the attestation request from the target system to an attester, wherein sending the attestation request from the target system to the attester comprises sending a subset of information contained in the attestation request to the attester;

collecting information regarding the specific dynamic properties by invoking measurement agents that perform measurements on software executing on the target system, wherein the collected information corresponds to the subset of information sent from the target system to the attester;

sending an attestation response from the attester to the appraiser, wherein the attestation response includes information regarding the reliability of the attestation

response, wherein the information regarding the reliability of the attestation response identifies an attestation architecture; and

making a trust decision at the appraiser regarding the target system based on information regarding the specific dynamic properties and the reliability of the attestation response contained in the attestation response.

24. The computer program product of claim **23**, wherein the operation of sending the attestation request comprises sending the attestation request to an attester residing on a same host as the target system.

25. A system capable of making trust decisions regarding a target system, comprising:

one or more processors; and

a memory configured to store computer instructions that, when executed by the one or more processors, cause the one or more processors to:

send an attestation request from an appraiser to the target system, wherein the attestation request comprises a subset of information contained in an original request from the appraiser;

receive an attestation request from the appraiser at a target system, wherein the request includes queries regarding specific dynamic properties of the target system needed by the appraiser to make trust decisions regarding the target system;

send the attestation request from the target system to an attester, wherein sending the attestation request from the target system to the attester comprises sending only a subset of information contained in the attestation request to the attester;

collect information regarding the specific dynamic properties by invoking measurement agents that perform measurements on software executing on the target system, wherein the collected information corresponds to the subset of information sent from the target system to the attester;

send an attestation response from the attester to the appraiser, wherein the attestation response includes information regarding the reliability of the attestation response, wherein the information regarding the reliability of the attestation response identifies an attestation architecture; and

make a trust decision at the appraiser regarding the target system based on information regarding the specific dynamic properties and the reliability of the attestation response contained in the attestation response.

26. The system of claim **25**, wherein the computer instructions are configured to cause the one or more processors to send the attestation request by sending the attestation request to an attester residing on a same host as the target system.

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